Standards in Power Electronics

by Peter Wilson

Power Electronics is a rapidly growing field, with an accelerating pace of technological change. This combination is a challenge for industry professionals trying to keep up to date with the regulatory and standards requirements and also the standards bodies (such as the Institute of Electrical and Electronics Engineers or IEEE) to ensure that the published standards are up to date. Standards are vitally important for ensuring that products conform to standard levels of functional interoperability, performance, safety and reliability. This is essential at all levels of scale from consumer products such as electric toothbrushes to cars and aircraft. There are a plethora of standards and regulatory bodies and this can lead to confusion, ignorance and inadvertent problems. These could possibly be averted if designers and product engineers had a greater awareness of not only which standards were required, but also some idea of how to interpret and implement them. This article is intended to assist power electronics engineers navigate these difficult and complex issues, and give some insight on how best to handle the use of standards. In order to accomplish this, I will use a number of very commonly asked questions by practicing engineers that have been posed to me in my standards role within the IEEE Power Electronics Society (PELS), and hopefully the answers will be constructive and useful. In addition, there are significant activities looking to establish a roadmap for wide bandgap power semiconductors, and while this is not directly a standard as such, it is closely related to a number of standards activities.

Which standards do I need to know about?

This is a common question often asked by engineers struggling to make sure they adhere to the correct standards. This obviously depends on the industry sector you are operating in. In many industries there may be "known" key standards and the most relevant standards body will also often be highly industry dependent. The IEEE is one of the world's most important standards organizations and in many cases it is true to say that the IEEE standard will be the *de facto* global standard. A very good example of this is the IEEE standard 802 (and it's various constituent standards) relating to computer networking – that have become ubiquitous. The use of the phrase "*de facto"* is important, as it is often the adoption by an industry that drives the use of a particular standard, rather than legislation *per se*. Other standards bodies in addition to the IEEE have a major influence on industry adoption including the International Electrotechnical Commission (IEC), the American National Standards Institute (ANSI), the International Organization for Standardization (ISO), the Society of Automotive Engineers (SAE), European Committee for Standardization (CEN), and a large number of regional or national standards bodies worldwide. These are often closely linked to regulatory bodies at governmental level who will seek to enforce certain standards in legislation at a national level. An example of such a national approach is the use of the "Kitemark" in the UK, which is a product and service quality certification mark defined and authorized by the British

Standards Institution (BSI). The role of this mark is to ensure that products sold in the UK conform to certain safety standards – particularly important for safety equipment such as helmets or protective clothing for example.

A nuance in the standards world is the use of the generic term “standard” to encompass not only mandatory activities, but also guidelines and recommended practices. These related standards are not necessarily binding or legally enforced, but rather provide a framework for the implementation of good practice or providing information to consumers to assist them in making informed choices. A good example of this is the recently published IEEE Std 1789 - IEEE Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers [1]. This recommended practice provides information that has been obtained by researchers and engineers in this technical area to enable some standardization of terminology and metrics for the comparison of LED lighting products in a sensible manner.

How are standards developed?

It is interesting to note that the vast majority of standards in electronics and electrical engineering were not developed by bureaucrats or legislators, but rather by engineers themselves. These same engineers usually provide their time and expertise as volunteers, working together for the benefit of the engineering community and the overall good of everyone. Of course, it would be naïve to assume that companies do not have a vested interest in ensuring they have an input to standards, however each standards body takes great care to ensure that no one company can dominate the process and there are usually strict rules to ensure that working groups and voting procedure cannot be skewed by one company or industry sector.

The approach within the IEEE to creating a new standard is shown diagrammatically in Figure 1.

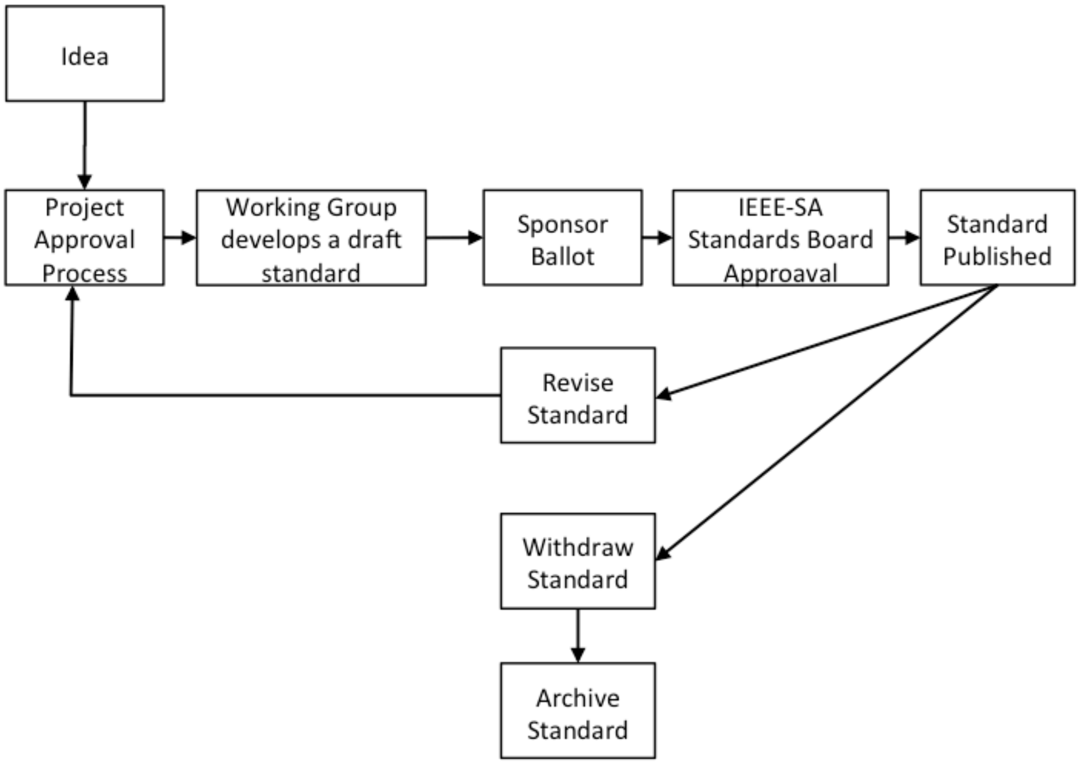

Figure 1: The IEEE standards process.

The first stage in any new standards process is the development of an idea. This can be an individual or a group, however once this has taken place the idea must be worked up into a proposal for a new standard. This can be relatively brief, however the scope of the proposed standard should be clear and the rationale for a new standard should also be clear. At the same time as the proposal has been developed, the appropriate technical society or societies to develop the standard should be identified, and they can shepherd the new draft through the process – this is termed the "sponsor". This is not mandatory, however it is highly recommended to give the working group exposure among the technical community that is relevant to the proposed standard. At this point the individual leading the draft standard should then create a "PAR" - Project Authorization Request. This is considered by the IEEE Standards Association and at this stage, if approved, a project number is assigned, which will become the number of the new standard if the process is completed.

At this stage, the working group needs to be formed, and this will generally consist of volunteers in that technical area who are willing and able to contribute to creating the standard draft. This can take quite a significant amount of time, however the overall time for the approval process is 4 years, and so it is not infinite. After the draft has been developed into a state where the working group is happy, a balloting pool can be formed whose members will vote on the new standard. The main role of the ballot is to ensure that a large enough majority of the community finds the new standard acceptable, and that all relevant concerns have been addressed. It is beyond the scope of this article to describe the full details of the process and these can be found on the IEEE Standards Association website [2].

Once the ballot has been passed, then the draft standard is passed to the IEEE Standards board for final approval and editorial review, and once this process has completed, the standard can be published. There is a mandatory period of review and update for the standard after 10 years (this used to be 5 years), at which point the standard can be renewed as is, revised, or withdrawn. If the latter, the standard will then be archived.

What about roadmap activities – relating to wide band gap devices?

In addition to standards, the IEEE Power Electronics Society Standards Committee (PELSC) has been instrumental in the development of the International Technology Roadmap for Wide Bandgap Power Semiconductors (ITRW). There are clear needs from industry, academia, education and public authorities to have a reliable and comprehensive view on the strategic research agenda and technology roadmap for wide bandgap power devices. There have been many roadmaps over the years in a variety of technical fields, perhaps the most famous being the International Technology Roadmap for Semiconductors (ITRS) [3] – which has been primarily driven by the deep sub-micron silicon based industry, with Moore's law at its heart.

The role of the ITRW is to provide reference, guidance and services to future research and technology development in this area. The goals of the ITRW are to publish a clear technology roadmap every two years, white papers setting out clear technology statements, position papers, defining a strategic research agenda, coordinating information dissemination and community building events and providing operational support to the wide band gap power semiconductor community.

The structure of the ITRW working group is as shown in Figure 2, with a steering committee that consists of leadership from societies, industry, government and academia bodies. The participation and leadership of industry is at the heart of the ITRW process and therefore in addition to key industry people involved on the steering committee there will be a wider industry advisory board that has a specific role of ensuring that the ITRW is relevant and technology driven.

The steering committee will also have strong technical representation from the specific technical working groups defined in Figure 2, ensuring that a broad participation of individuals across all aspects of wide band gap power semiconductor technologies are represented. As with the steering committee, there will be extensive industry participation in the individual working groups.

The structure of the ITRW has been designed to be inclusive and participation is open, in order to ensure that decisions taken are fair and neutral, the voting membership of the steering committee broadly follows the conventional IEEE approach taken for standards activities in that no one company, geographical grouping or constituency can dominate. In the early stages of the ITRW existence, the steering committee has been formed based on interest and knowledge of the field, however over time it is envisaged that the future executive officers will be elected as the organization becomes self-sustaining.

As well as the broad technical groupings shown, there will be underpinning technology interests shared across the technical working groups such as reliability, data sheets, testing, design techniques and these will be developed across the working groups where appropriate.

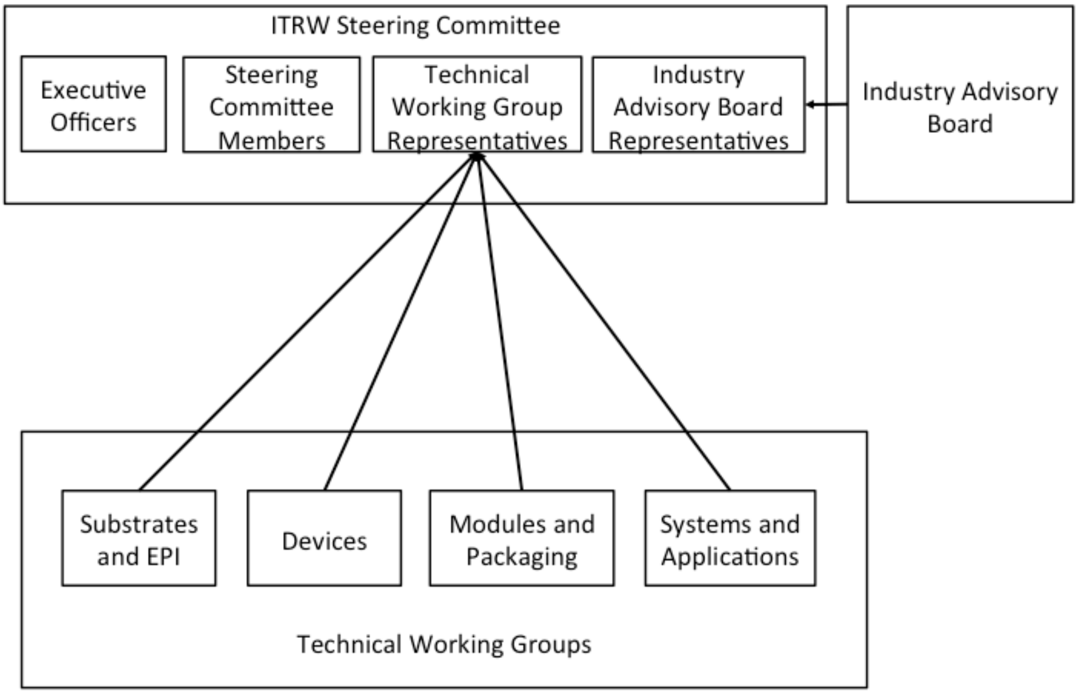

Figure 2: ITRW organizational structure.

What is the governance of the ITRW?

The Steering committee consists of representatives from relevant societies, associations and alliances, i.e., PELS, ECPE, CWA, with a membership per term for 3 years. The Chair (PELS) and co-chairs will be elected. This is the decision making body for ITRW, with 2/3 of the total votes. The steering committee has been constituted to ensure that a balance exists between members from academic, industrial and governmental backgrounds.

The Subcommittees and working groups consist of volunteers of internationally leading experts from both academia and industry and is the working body of ITRW. The chair and co-chairs of each sub group will initially be appointed by the steering committee.

The Industrial advisory board consists of peoples from relevant companies representing the complete value chain of this industry and the global geographic distribution. Its role is to provide inputs and advice to the steering committee. The chair and co-chairs are to be elected by the board.

How will the ITRW operate?

The idea is that the ITRW will be a neutral forum providing an open platform based on the contribution of global leading experts as volunteers. There will be members' meetings: twice per year, in combination with major conference/event to ensure that maximum participation, and there will be regular other meetings or workshops outside these major meetings. The technology roadmap will update once every 2 years. The white paper and Strategic Research Agenda will be defined according to need and events will be organized according to need. The ITRW will use the web for information sharing and advertisement.

How can we establish a framework of standard metrics for wide bandgap?

One of the major challenges for the power electronics community in the comparison of power electronics devices and systems is being able to have a framework of standard metrics to enable this comparison to take place. The well known "Moore's Law" is the observation that the number of transistors fabricated in a dense electronic circuit doubles every two years [12]. While this has been useful as a specific metric for the silicon device community that basically establishes a rule of thumb for the "cutting edge" of device technology based on dimension alone, and in fact it has led to a number of related trends in the Silicon world such as power loss, switching speed and complexity, these do not translate directly into the power electronics world and more specifically wide bandgap semiconductors such as silicon carbide (SiC) or gallium nitride (GaN). From the power electronics standpoint a key parameter is the $R_{ds}(on)$ resistance and this provides a suitable measure of the basic device performance in terms of the relationship between $R_{ds}(on)$ and the breakdown voltage. When the curves for silicon (Si), SiC and GaN are compared it can be seen that there is a fundamental measure of the limit for each technology as shown in Figure 3.

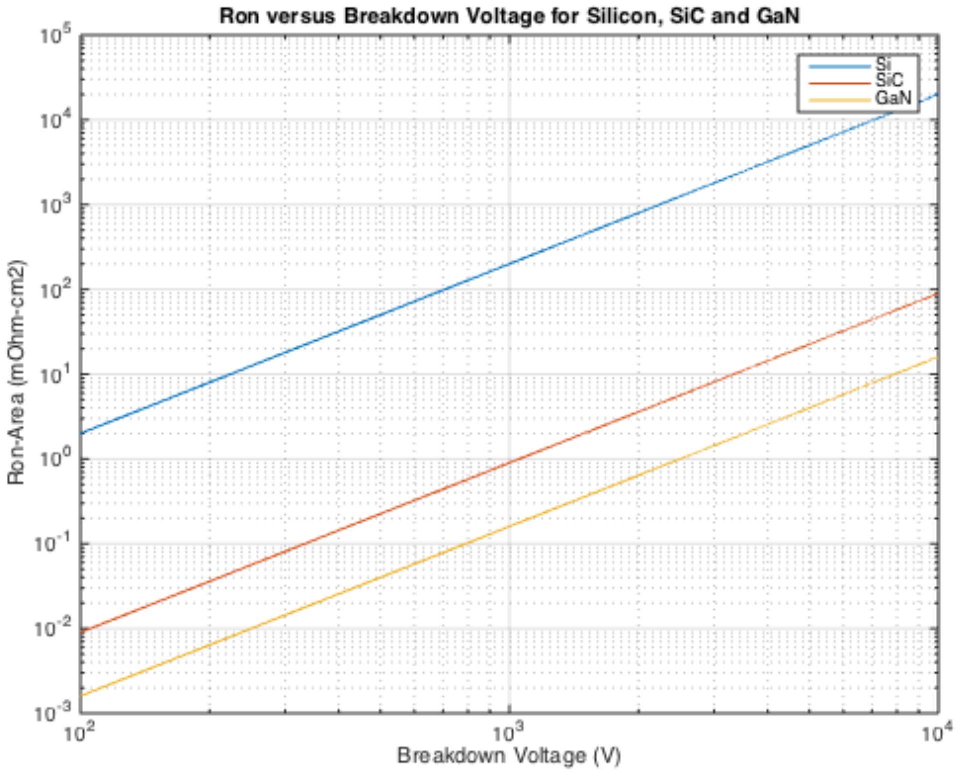

Figure 3: R_{ds}(on) resistance versus breakdown voltage for Si, SiC and GaN technologies.

Useful though this metric is, in fact it is not the complete picture. If we compare the thermal performance of Si and SiC, for example, it is well known that SiC devices can operate at much wider temperature ranges than Si, and as such their range of operation is much wider. Also, their ability to tolerate higher temperatures makes it less important to ensure that the devices are maintained at a lower temperature (as would be the case for Si devices). This, in conjunction with a much lower on resistance (and consequently lower static power loss), makes temperature an orthogonal aspect of the metric framework potentially to be considered. Another issue that is of particular relevance to the power electronics community is that of reliability. Some wide bandgap devices are at a very early stage of commercialization and therefore the technology is immature enough to leave questions over reliability when deployed over a long period.

One of the particular difficulties in establishing this framework is also the wide range of application of each aspect of these devices, for example running at a high temperature, or perhaps extensive periods of high power operation. The other aspect is how can we predict the performance in a particular module, package or system, when those aspects may influence performance equally as much as the device itself? For example, a SiC device may be intrinsically robust, but the driver may not be, especially if it is integrated using a wire-bonded package.

The role of the ITRW is to establish some of the key criteria in a framework of metrics for wide bandgap power semiconductors, in the context of power electronic systems, to enable specific technical work and standards activities to be undertaken.

What are examples of typical standards relevant for power electronics?

There are a large variety of IEEE standards for power electronics activities. IEEE Std 1573 [4] - Recommended Practice for Electronic Power Subsystems: Parameters, Interfaces, Elements, and Performance – has been developed for the overall design of power electronics modules and sub-systems and includes guidelines for effective and efficient design of power electronics. This standard provides guidance on interface definitions and application, including parametric values for power electronic subsystems consisting of single or multiple elements. The recommended practice applies to ac-dc and dc-dc electronic power subsystems. The range of power subsystems includes dc, single phase, and three-phase inputs, with elements having power levels from a fraction of a watt to 20 kW. The voltage range is 600 V and below, at a frequency or frequencies of dc -1 kHz (although switching frequencies can of course be much higher than this range). For higher power converters, there is 295-1969 - IEEE Standard for Electronics Power Transformers [5], which relates to sine wave or poly-phase voltages, and this will be of relevance to those working in "Grid" related activities.

Of course, there are many specific technical areas where standards must be adhered to and a highly popular area at the moment is that of solar inverters. For example, for a solar inverter to be used in Europe it must conform to the following standards: EN 50524 [6], current version published in 2010 and covers the data sheet and name plate for photovoltaic inverters. EN 50530 [7], also current version published in 2010 defines the methods for testing the overall efficiency of grid connected photovoltaic inverters. IEC 61683, current version published in 1999 [8], defines the procedure for measuring efficiency and power conditioners. What this means in practice is how to assess the power level, input voltage, output voltage, power factor, harmonic content, load non-linearity and temperature. EN62109 [9] deals with the safety of the power conversion equipment for use in PV systems and defines the minimum requirements for protection against fire, mechanical, electric shock and other requirements.

In addition to the need for specific power electronics-related standards, there may also be module level or consumer product standards, particularly for safety. For example, if a dc-dc converter needs to be integrated in a communications system it will need to satisfy the safety requirements in telecommunications [10] or information technology equipment [11].

These standards are simply a fraction of the standards applicable to power electronics systems today, but will give the reader an idea of the scope of individual standards and highlight some of the key issues for power electronics designers.

Conclusions

The role of standards in power electronics systems has become revitalized with the development of major steps forward due to wide bandgap power semiconductor devices, particularly in SiC and GaN. The step change in performance and thermal tolerance in particular has led directly to the need for new standards and definitions to be produced, both for researchers and industry. It is an exciting time to be in the power electronics field and there are great opportunities for the power electronics community to come together to define a standard approach to manage the adoption of these exciting new technologies.

About the Author

Peter Wilson (p.r.wilson@bath.ac.uk) is Professor of Electronics and Systems Engineering in the Department of Electronic and Electrical Engineering, University of Bath, U.K. He received his BEng from Heriot-Watt University, MBA from Edinburgh Business School and PhD from the University of Southampton, and has industrial experience at Ferranti, GEC-Marconi, Analogy, Inc. prior to taking up his previous academic post of Associate Professor at Southampton in the School of Electronics and Computer Science. He is a Fellow of the IET and BCS, and a senior member of the IEEE, and is currently serving as Executive Vice President of Standards for the IEEE Power Electronics Society.

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Note: Links checked November 2016, however not all standards documents are freely available

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